ZooKeys 1097: 117–132 (2022)
doi: 10.3897/zookeys.1097.76426
https://zookeys.pensoft.net

RESEARCH ARTICLE

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Tadpole soup: Chinantec caldo de piedra and behavior of *Duellmanohyla ignicolor* larvae (Amphibia, Anura, Hylidae)

Carlos A. Flores[1], Medardo Arreortúa[1], Edna González-Bernal[2]

1 *CIIDIR Unidad Oaxaca, Instituto Politécnico Nacional, Laboratorio de Ecología de Anfibios (ECA), Hornos 1003, Col. Noche Buena, 71230, Santa Cruz Xoxocotlán, Oaxaca, Mexico* **2** *CONACYT - CIIDIR Unidad Oaxaca, Instituto Politécnico Nacional, Laboratorio de Ecología de Anfibios (ECA). Hornos 1003, Col. Noche Buena, 71230, Santa Cruz Xoxocotlán, Oaxaca, Mexico*

Corresponding author: Edna González-Bernal (ednagbernal@gmail.com)

Academic editor: Annemarie Ohler | Received 14 October 2021 | Accepted 2 March 2022 | Published 21 April 2022

http://zoobank.org/BBF9F262-8B29-4E27-A437-A2A6DB319D07

Citation: Flores CA, Arreortúa M, González-Bernal E (2022) Tadpole soup: Chinantec caldo de piedra and behavior of *Duellmanohyla ignicolor* larvae (Amphibia, Anura, Hylidae). ZooKeys 1097: 117–132. https://doi.org/10.3897/zookeys.1097.76426

Abstract

Although amphibian consumption by humans has been reported globally, this practice is not well studied despite its direct implications to the decline of amphibian populations. The International Union for Conservation of Nature (IUCN) recognizes the need to document the use and trade of species to be considered in assessing their extinction risk. Here the consumption of *Duellmanohyla ignicolor* tadpoles is documented. It is a micro endemic species categorized as Near Threatened (NT) consumed in a traditional dish called "caldo de piedra" (stone soup) prepared by the Chinantec people (Tsa Ju Jmí') in Oaxaca, Mexico. Through conversations with local people and stream monitoring, the behavior of tadpoles of this species was documented and aspects of their exploitation and habitat use described. Places where caldo de piedra is still consumed were determined and using a spatial analysis with Geographic Information Systems, the distribution of the species in relation to those localities was analyzed. A number of other areas where tadpoles of this species might also occur and be exploited is predicted. In conclusion, the school behaviour, surface feeding, and the preference for deeper waterbodies that these tadpoles exhibit makes them vulnerable to being caught in large quantities. As they are consumed locally, are not commercialized, and the species distribution range is wider than caldo de piedra consumption, this implies a low risk for their populations. However, the tadpoles' reliance on streams with depths $\bar{x}$ = 60 cm and flux $\bar{x}$ = 0.65 m/s reduces the availability of sites for their optimal development.

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Keywords
Amphibian, consumption, hot-rock cookery, Mexico, natural history, stream dwellers

Introduction

Amphibians are a vertebrate group at high extinction risk due to habitat transformation, alien species introduction, contamination, emergent diseases, climate change, and human exploitation (Kats and Ferrer 2003; Whittaker et al. 2013). Currently, at least 41% of all known anuran species are at risk and almost half show population declines (Hoffmann et al. 2010; Stuart et al. 2010; IUCN 2021a). Of the various ways that humans use amphibians, their use as food is poorly studied (Tyler et al. 2007; Gratwicke et al. 2010; Akinyemi and Ogaga 2015; Grano 2020). Amphibian consumption by humans has received far less attention than mammal and bird consumption (Ibarra et al. 2011; Chaves et al. 2019; Dobson et al. 2019; Ripple et al. 2019) and it is usually reported by social scientists who frequently fail to identify the species involved. Amphibian consumption data are often present in the grey literature and not evaluated in the context of species risk (González-Hernández 2019). Frogs have been part of the human diet since the early Pleistocene and archeological remains suggest that this consumption was not random (Kyselý 2008; Blasco et al. 2011). This practice continues in different cultures across the globe (Cooke 1989; Onadeko et al. 2011; Akinyemi and Ogaga 2015; Ohler and Nicolas 2017) and in some cases it can become a tangible species threat. For example, in Indonesia, *Fejervarya cancrivora* (Gravenhorst, 1829) (Least Concern) and *Limnonectes macrodon* (Duméril & Bibron, 1841) (Least Concern), are exploited for both local consumption and large scale exportation. Since these species are not raised in captivity, it can be assumed that all consumed individuals are collected from the wild (Kusrini and Alford 2006).

In general, amphibian consumption studies focus mainly on adult anurans with less attention paid to tadpole exploitation, even though larvae consumption might imply the need to capture larger numbers of individuals to match an equivalent nutritional yield to that of adult consumption. For example, tadpole consumption of the Western Ghats (India) endemic frog *Nasikabatrachus sahyadrensis* (Biju & Bossuyt, 2003; Purple frog), reaches up to 50% of the available individuals yearly and the proportion of collected/available tadpoles increased to 70% from 2008 to 2012, representing a direct threat to the species' survival (Thomas and Biju 2015).

Despite a genuine concern about amphibian overexploitation for human consumption and its effects on species population sizes (Stuart et al. 2004; Kusrini and Alford 2006; Onadeko et al. 2011; Talukdar and Sengupta 2020), data on species use are still scarce in relation to other threats considered by the IUCN. For example, although amphibian cultural importance and use has been widely documented in México, for Oaxaca, the state with the richest amphibian diversity in the country, only

7.55% (12/159) of the amphibian species present a general scheme of use according to the IUCN (Parra-Olea et al. 2020; Mata-Silva et al. 2021; IUCN 2021b).

Regarding tadpole consumption by humans, it is only superficially mentioned in historical writings with the species remaining unidentified (Aguilar and Luría 2016). Even now, in rural or indigenous communities where tadpoles are eaten, researchers tend to mention it only anecdotally with no formal studies on this practice.

During herpetofauna surveys in Santa Cruz Tepetotutla, our field guide Pedro Osorio-Hernández brought to our attention the local consumption of tadpoles in a soup called "caldo de piedra" (stone soup in English). Caldo de piedra is an ancient dish that is traditionally prepared on the bank of the river, using a container or rock holes in which river water, fish meat, vegetables, and raw seasonings are placed and cooked by adding heated stones. In order to study this activity, identify the tadpole species involved, and document other biological and cultural information, we conducted conversational interviews, rivers and streams surveys, spatial analysis through Geographic Information Systems, and a literature review. Here we report that tadpoles of the Sierra Juarez brook frog *Duellmanohyla ignicolor* (Duellman, 1961) are consumed in caldo de piedra in the Chinantla region, in Oaxaca Mexico. We also report on aspects of the tadpole's behavior and natural history relevant to its exploitation and survival.

Materials and methods

Study area

Santa Cruz Tepetotutla (17.7391°N, -96.5582°W) is a Chinantec indigenous community located in the southwest portion of San Felipe Usila municipality in the state of Oaxaca, Mexico (Fig. 1). It forms part of an indigenous region known as "La Chinantla", which is subdivided in three ecophysiographic subregions known as higher, medium, and lower Chinantla due to altitudinal differences (de Teresa 1999). It includes 14 municipalities and 258 communities. Throughout the region, Chinantec language is spoken in 11 variants (INEGI 2010). In their own language, Chinantecs refer to themselves as *Tsa ju jmí'*, which means "people of the ancient word" (INPI-INALI 2020).

Santa Cruz Tepetotutla preserves 9,670 ha of montane cloud forest under the Indigenous and Community Conserved Area (**ICCAs**) modality, certified by National Protected Area Commission in Mexico (**CONANP**). It supports the presence of several threatened species (Simón-Salvador et al. 2021). The main vegetation is montane cloud forest, with several streams filling two main waterways, the Tlacuache river (Fig. 2A) and the Perfume River, which discharge their waters into the Usila River that finally reaches the Presidente Miguel de la Madrid Hurtado dam in the lower Chinantla (INEGI 2014).

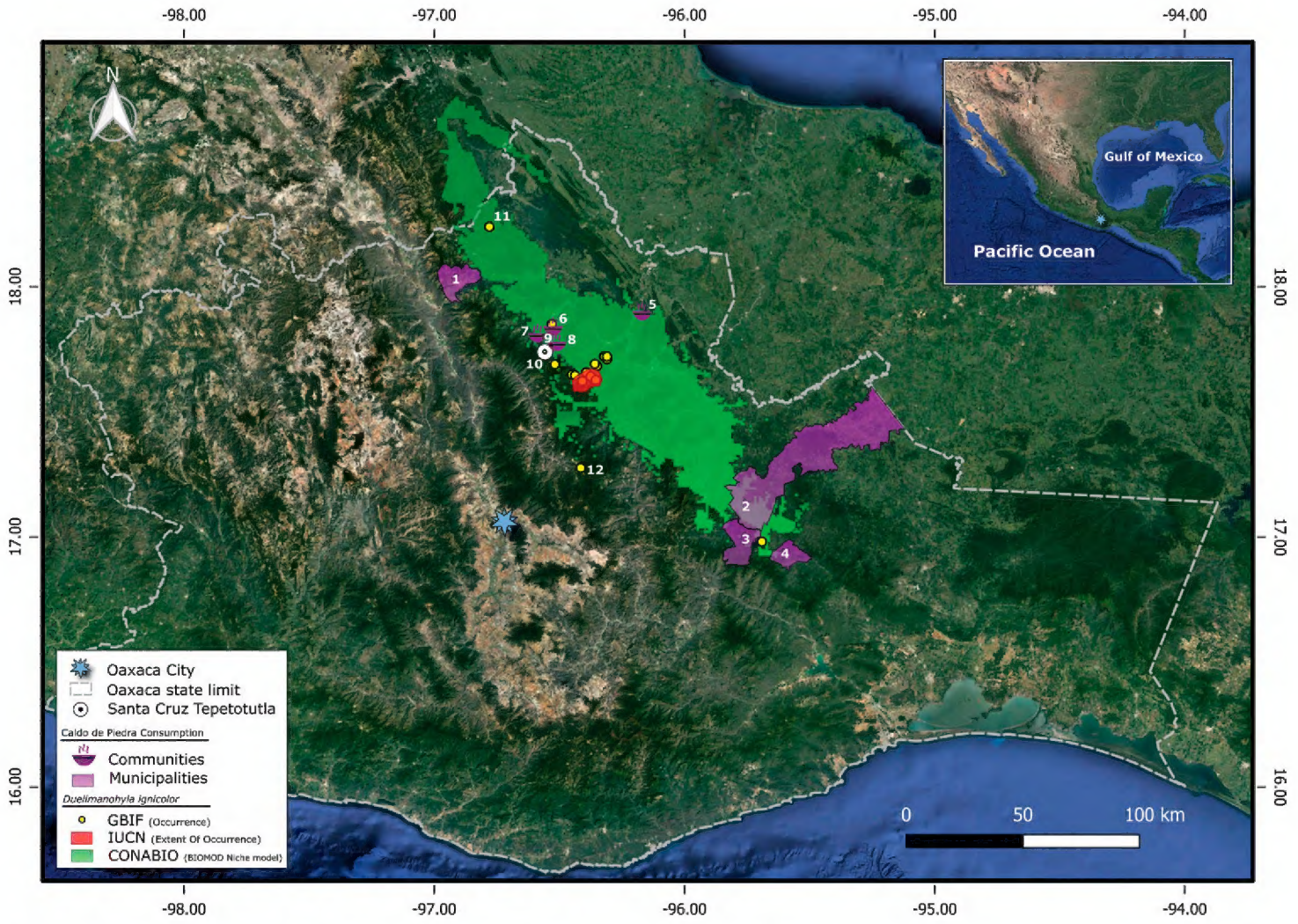

Figure 1. Study site. Santa Cruz Tepetotutla locality in Oaxaca, Mexico represented by a white dot. The red polygon represents the Extent Of Occurrence elaborated by IUCN. The green polygon represents the CONABIO model. GBIF occurrences are represented by yellow dots. Municipalities and communities where caldo de piedra is consumed are represented by areas in purple and by a purple soup icon respectively.

Species

Duellmanohyla ignicolor (Fig. 2B) is an hylid frog endemic to Oaxaca, Mexico and restricted to the Sierra Madre de Oaxaca (**SMO**) physiographic region (Duellman 1961; Duellman 2001; Ortiz- Pérez et al. 2004). According to the IUCN it is catalogued as Near Threatened (**NT**) and it has not been considered as used in trade or for human consumption (IUCN 2020).

Interviews

We conducted interviews with men and women in the community to ask mainly if caldo de piedra was still prepared locally. If it was, we asked which tadpoles were used in its preparation, where, when, and by whom they are collected, how they taste, and how they know which are edible or not.

River surveys

As the interviewees referred to tadpoles captured at the main river (Río Tlacuache); we surveyed it at accessible areas along five sections of approximately 50 m long, looking

for tadpoles with the described behavior. Once found we corroborated that those were the tadpoles used to prepare caldo de piedra by talking to a family that was eating caldo de piedra at that moment by the river. Species identification was made according to literature (Duellman 1961).

We conducted stream surveys to determine tadpole presence and stream characteristics in other waterways in the region. A total of ten waterways in addition to Río Tlacuache was surveyed in 50 m long sections. The characteristics assessed were depth, width, and water current speed measured with a flow meter Flow Watch 30 (JDC Electronics SA). Surveys took place between April and August in 2019.

Literature review and spatial analysis

To give a better perspective on caldo de piedra consumption and explore potential areas where it can be prepared with *D. ignicolor* tadpoles (Fig. 2C) as an ingredient, we reviewed ethnographic research conducted in the region related to this cooking style and cuisine. An approximation of the likelihood of *D. ignicolor* tadpoles being a component of contemporary caldo de piedra, was made with a spatial analysis that compared the species distribution with areas where this dish is consumed. Available geospatial information for *D. ignicolor* was obtained. These included the potential distribution area elaborated by the Comisión Nacional para el Conocimiento de la Biodiversidad (**CONABIO**) (Ochoa-Ochoa and Flores-Villela 2016), the Extent Of Occurrence (**EOO**) polygon elaborated by IUCN, and the species occurrence records from Global Biodiversity Information Facility (GBIF 2021). The data was compared with the sites where the elaboration of the caldo de piedra is reported in literature. The information was analyzed on QGIS 3.16.4 (Quantum GIS Development Team 2021).

Results

Interviews

Caldo de piedra with *Duellmanohyla ignicolor* tadpoles as an ingredient is still prepared and eaten in Santa Cruz Tepetotutla, although these days the main animal protein in the soup is farmed *mojarra* (*Oreochromis niloticus* (Linnaeus, 1758) or *Coptodon rendalli* (Boulenger, 1897)). During April when tadpoles are abundant, people prepare the soup both at the river and at home. Children are usually the ones that capture the *D. ignicolor* tadpoles, especially during the Easter holidays (April) when they go swimming in the river. The tadpoles are captured in plastic bags, by hand, and even with hats or caps. Innards are removed by squeezing the tadpole's body with the fingers. Once "cleaned", they are placed in a bowl with tomato, onion, chili, salt, wild coriander, and water and then the mixture is brought to a boil by adding small hot stones until the soup is cooked.

Duellmanohyla ignicolor tadpoles are considered cleaner and thus more edible than tadpoles from other stream species because they swim at the water surface (Fig. 2D).

The tadpoles of other species in the streams are bottom dwellers and are perceived of as dirty because of their contact with the sediment. The tadpoles that are consumed are between Gosner stages 30 and 35. Later stage larvae with easily visible legs are not considered edible. Interviewees described the tadpoles as having a delicious fish-like flavor (Fig. 2E).

Duellmanohyla ignicolor tadpole habitat use and behavior

Of the ten surveyed streams in the locality, we found *D. ignicolor* tadpoles in only one of them (Bado stream) apart from the main river (Río Tlacuache). *Duellmanohyla ignicolor* tadpoles prefer deeper pools available at the edge of the stream ($\bar{x}$ = 60 cm ± SD = 7.6, n = 12 in used streams vs. $\bar{x}$ = 11.9 cm ± SD = 6, n = 54 in unused streams). Water bodies with faster currents ($\bar{x}$ = 0.65 m/s ± SD = 0.11, n = 12 in used streams vs. $\bar{x}$ = 0.31 m/s ± SD = 0.26, n = 54 in unused streams) and that are deeper at the center ($\bar{x}$ = 81.2 cm ± SD = 6.32, n = 12 in used streams vs. $\bar{x}$ = 20.8 cm, ± SD = 12.90, n = 54 in unused streams). Values of utilized waterways include measurements taken at the main river. Kruskal-Wallis test conducted on all measurements showed statistical differences P<.0001.

Duellmanohyla ignicolor tadpoles can be found at the river edge using pools formed by rocks. Most of the time, they are near to the water surface with head-up positions forming schools. It is possible to find groups composed of more than 100 individuals in ~ 4 m^2 (Fig. 2C, D). While in this position, they continuously move their mouthparts which suggests they might be feeding on suspending particles dragged by the water current or that land on the water surface. If disturbed by any unusual movement in the water, they move towards the rocks and cling to them using their large oral disc. They can also hide in the leaf litter or beneath the rocks located at the bottom of the pool. Large oral discs in this species are considered an adaptation to living in fast-moving currents (Caldwell 1974). At the study site, individuals at Gosner stage 36 reached up to 52 mm in total length.

At Río Tlacuache in Santa Cruz Tepetotutla, this species shares microhabitat with *Ptychohyla zophodes* (Campbell & Duellman, 2000) and *Incilius valliceps* (Wiegmann, 1833). In Arroyo Bado, they co-occur with *P. zophodes*. In contrast to *D. ignicolor* tadpoles, *P. zophodes* and *I. valliceps* tadpoles are benthic feeders so they spend most of the time at the bottom of the pools.

Caldo de Piedra and amphibian consumption by Chinantec people (Tsa Ju Jmí')

Caldo de Piedra was exclusively prepared by men, who dug a hole in the river sand and covered it with pozol leaves (*Calathea lutea* (Aubl) E. Mey. ex Schult, 1822) to prevent the water from escaping (river rock holes are also used). Chili, vegetables, and salt were placed inside and with a branch, some egg-sized rocks, previously heated in a campfire, were added in order to cook the food. When the water began to boil, a fish without entrails was added and cooked for 10–15 minutes. Finally, the broth was served in a plate made with pozol leaves or in a "Jícara", a bowl made of *Crescentia cujete* Linnaeus, 1753, and it was accompanied with "tortillas" (Weitlaner 1951; Bost 2009). There is

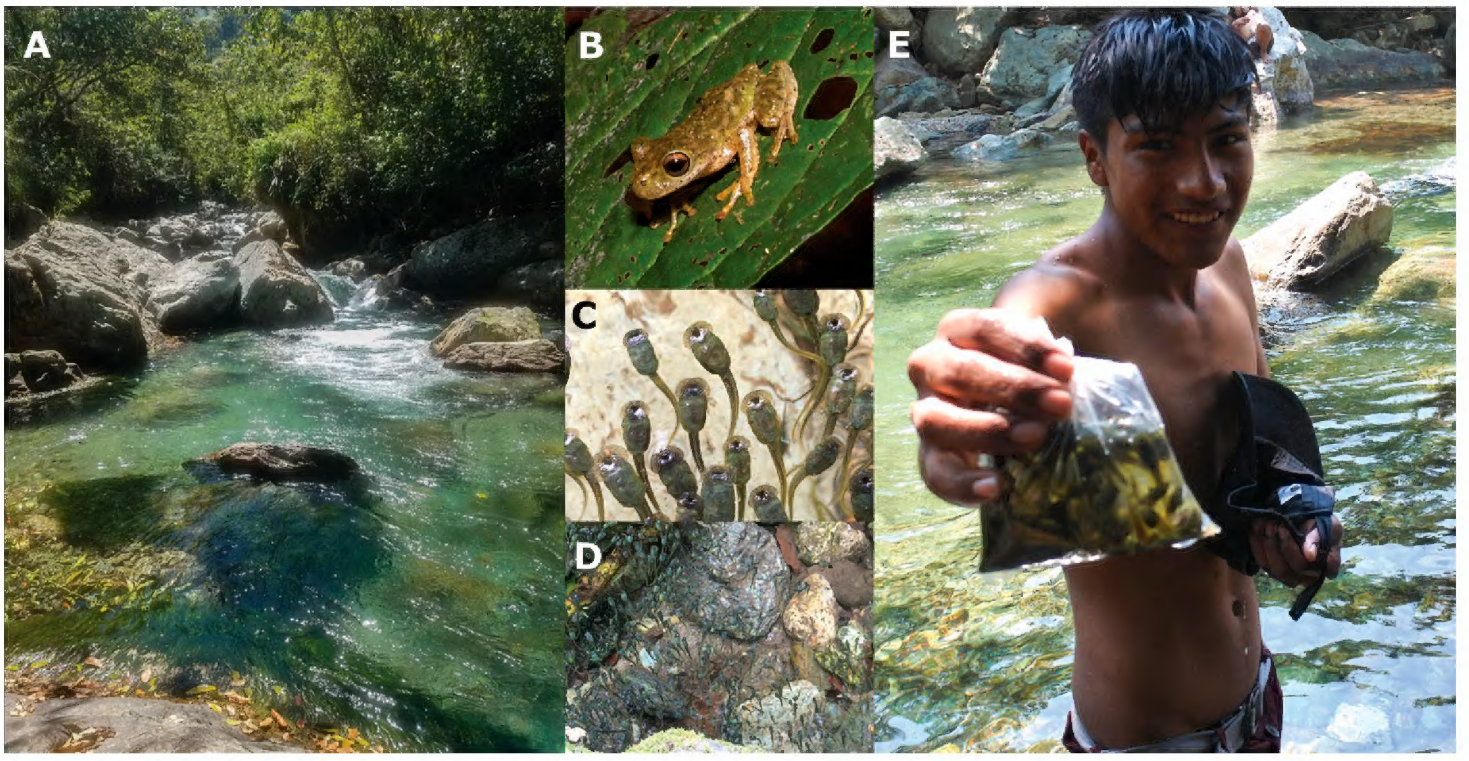

Figure 2. Aspects of *Duellmanohyla ignicolor* natural history and use **A** characteristic pools in the Tlacuache river where tadpoles aggregate **B** *D. ignicolor* adult **C** *D. ignicolor* tadpoles **D** school forming behavior **E** a teenager collecting tadpoles with a cap and keeping them in a plastic bag. Photographs: (**A, C, D, E**) by Edna González-Bernal; (**B**) by Medardo Arreortúa.

no agreement on when and by whom caldo de piedra was invented. Its ancient origin is claimed by some inhabitants of San Felipe Usila as a "millenary cooking practice uniquely developed by fishermen in his community" (Brulotte and Starkman 2014). The dish is based on a gendered division of labor where "women bathe and wash clothes in the river, but it's only adult men who fish and prepare the caldo. With the finished soup finally being offered to women and children" (Brulotte and Starkman 2014). Nevertheless, similar dishes are present in other Oaxacan cultures like Ayuk (Mixe) where it is named "caldo de playa" since it is made at the riverbanks (Nahmad 2003; Sánz 2015). There is evidence that this type of hot-rock cooking has been long used in by North American cultures (Thoms 2008), with the same cooking principle know to occur in Europe since the late Aurignacian (ca. 32,000–33,000 B.P.) and similar cooking technology occurring elsewhere in the world (Thoms 2009).

One of the common characteristics among the different descriptions of caldo de piedra from Oaxaca is the use of ingredients like tomato, chili, spices, salt, and fish (bobo fish *Joturus pichardi* Poey, 1860 and trout *Oncorhynchus mykiss* Walbaum, 1792) as the main base, but also river shrimp, prawns, and snails (Mejía and González 2019). However, no amphibians as either as tadpoles or adult frogs have been previously mentioned.

Spatial analysis

There are currently two species distribution models for *D. ignicolor* (Fig. 1). The first, presented by CONABIO uses the BIOMOD platform and suggests that the distribution of the species is 6605 km^2 including the states of Oaxaca, Puebla, and

Table 1. Location of communities and municipalities referred in Fig. 1. Inclusion (✓) or exclusion (✗) in the CONABIO and UICN distribution models for *Duellmanohyla ignicolor*. Species occurrence refers to real occurrence data.

Map id	Municipalities	Conabio	IUCN	Species Occurrence	Caldo De Piedra Consumption	Coordinates
1	Mazatlán Villa de Flores	✗	✗	✗	✓	18.032542°N, -96.915527°W
2	San Juan Cotzocón	✓	✗	✗	✓	17.160736°N, -95.783228°W
3	San Miguel Quetzaltepec	✓	✗	✓	✓	17.018643°N, -95.830581°W
4	Santiago Ixcuintepec	✓	✗	✗	✓	16.934397°N, -95.623581°W
	Communities					
5	San José Chiltepec	✗	✗	✗	✓	17.948046°N, -96.169111°W
6	San Felipe Usila	✓	✗	✗	✓	17.887505°N, -96.524692°W
7	San Juan Bautista Tlacoatzintepec	✓	✗	✗	✓	17.859707°N, -96.586562°W
8	Santiago Tlatepusco	✓	✗	✗	✓	17.825197°N, -96.509955°W
9	San Antonio del Barrio	✗	✗	✗	✓	17.758098°N, -96.556130°W
10	Santa Cruz Tepetotutla	✗	✗	✓	✓	17.739398°N, -96.558096°W
11	Ejido Clemencia	✓	✗	✓	✗	18.240000°N, -96.780000°W
12	Capulalpam de Méndez	✓	✗	✓	✗	17.275553°N, -96.414522°W

Veracruz (Ochoa-Ochoa and Flores-Villela 2016). The second model, elaborated by IUCN, uses EOO parameter and suggests that the species is restricted to only 91 km^2 within Sierra Madre de Oaxaca physiographic region (IUCN 2021b).

Occurrence records for the species obtained from GBIF (gbibID: 1897584918, 1572339861), CONABIO and MZFC (Museo de Zoología de la Facultad de Ciencias, UNAM) (Ochoa-Ochoa and Flores-Villela 2016), include three localities outside the IUCN model (Table 1). The first corresponds to a specimen collected in Capulalpam de Méndez (Departamento de Zoología, Instituto de Biología IBUNAM, CNAR24801). The second record is an observation of several adults in a stream in San Miguel Quetzaltepec municipality (Levy N. Gray, pers. comm.). It is outside south the area of the UICN model and represents the most southern known occurrence of the species. The third record corresponds to a series of specimens collected in Ejido Clemencia, a locality in Santa María Chilchotla municipality, that represents the most northern known occurrence of the species (Ochoa-Ochoa and Flores-Villela 2016).

From our spatial analysis we determined that caldo de piedra is consumed in ten localities among three regions: La Chinantla (six localities), the Mixe region (three localities), and the Cañada region (one locality). From these ten localities, only six overlap with the CONABIO distribution model of *D. ignicolor* (Fig. 1), and none of them overlap with the IUCN distribution model. In only two localities (Santa Cruz Tepetotutla and San Miguel Quetzaltepec) the species occurrence has been confirmed; only in Santa Cruz Tepetotutla has it been confirmed that caldo de piedra is prepared with *D. ignicolor* tadpoles (Table 1).

Discussion

Documenting the human use of a species is fundamental to developing conservation measures. One cause of species' declines is human consumption linked to poor regulation. Educational programs deficient in environmental and ecological foci and few or no economic alternatives for people consuming the taxa are contributing to species' declines. Seventeen native amphibian species out of 411 in Mexico are known to be consumed by humans: *Agalychnis dacnicolor* (Cope, 1864), *Ambystoma dumerilii* (Dugès, 1870), *A. mexicanum* (Shaw & Nodder, 1798), *A. taylori* (Brandon, Maruska, & Rumph, 1981), *A. velasci* (Dugès, 1888), *A. altamirani* (Dugès, 1895), *A. granulosum* (Taylor, 1944), *A. lermaense* (Taylor, 1940), *Charadrahyla taeniopus* (Günther, 1901), *Dryophytes eximius* (Baird, 1854), *Lithobates forreri* (Boulenger, 1883), *L. tlaloci* (Hillis & Frost, 1985), *L. sierramadrensis* (Taylor, 1939), *L. montezumae* (Baird, 1854), *L. spectabilis* (Hillis & Frost, 1985), *Rheohyla miotympanum* (Cope, 1863) and *Rhinella horribilis* (Wiegmann, 1833) (Huacuz 2002; Casas-Andreu et al. 2004; Carpenter et al. 2007; Altherr et al. 2011; Velarde 2012; Aguilar and Luría 2016; González-Hernández 2019; IUCN 2021a). All these species are consumed at their adult stage. Tadpole consumption has only been formally reported for one native species: *Lithobates montezumae* (Baird, 1854) and one introduced species *L. catesbeianus* (Shaw, 1802) (Casas-Andreu et al. 2004; González-Hernández 2019).

We report the first record of *Duellmanohyla ignicolor* tadpole consumption in the country in a traditional soup called caldo de piedra. In Mexico, this meal is consumed in different localities in Oaxaca, but in Santa Cruz Tepetotutla, it is prepared with *D. ignicolor* tadpoles. This tadpole soup is consumed during the hottest months (April and May: Fernández et al 2012), when people go swimming in the river. Therefore, human predation of this species takes place at the main river of the locality. The rest of the year, the soup is prepared with fish.

Biological characteristics can make tadpoles of some species more exploitable than others, for example, *Nasikabatrachus sahyadrensis* (Biju & Bossuyt, 2003) tadpoles are collected in large numbers due to their practice of attaching themselves in groups to rock surfaces in waterfalls. Consequently, people easily sweep large numbers off the rocks using branches (Thomas and Biju 2015). Concerning *D. ignicolor* tadpoles, we registered three aspects that contribute to their exploitation by humans: their feeding behavior, their school formation (McDiarmid and Altig 1999), and their preference for deeper water pools.

Duellmanohyla ignicolor tadpoles feed on suspended particles by swimming near the water surface with head-up postures. While feeding, they form schools that facilitate their catch in big numbers. This schooling behavior is associated with protection against predators, temperature, and the effectiveness of feeding strategies (Blaustein and Waldman 1992; Blaustein and Walls 1995; Spieler 2003; Hase and Kutsukake 2019). However, this behavior makes them more vulnerable to human exploitation. As they swim near the water surface, people perceive them as clean and prefer them

over co-occurring tadpoles that exhibit a benthic behavior. Tadpoles with benthic behavior (*P. zophodes* and *I. valliceps*) are considered dirty due to their association with sediments.

Contrary to previous studies that mention that *D. ignicolor* tadpoles use shallow gravel-bottomed pools in streams (Duellman 2001), we found them in deeper water bodies with faster currents. The preference for deeper water has been associated with an anti-predatory strategy and as a way to reduce the chances of pool drying during the dry season (Borges-Júnior and Rocha 2013). However, this strategy might increase the chances of human exploitation, as humans use deeper water bodies to swim.

Concerning habitat use, *D. ignicolor* tadpoles can be found in waterbodies with faster currents. The existence of another stream used by *D. ignicolor* tadpoles from where they are not extracted ensures their local presence. However, most of the available streams in the locality present lower currents, and are not used by tadpoles of this species, even when we observed adult individuals on those streams. Differences in microhabitat preference among developmental stages have been reported in other amphibian species but their causes remain to be studied (Afonso and Eterovick 2007; Eterovick et al. 2010).

It will be necessary to determine the impact of reduced availability of optimal streams combined with human extraction. In this sense, everyone we spoke with referred to tadpole consumption as local and without commercial purposes. Nobody reported selling tadpoles and we have not heard about any trading with them. *D. ignicolor* tadpole consumption is not as threatening as in cases where large numbers of larvae are extracted yearly, i.e., *Nasikabatrachus sahyadrensis* (Thomas & Biju, 2015).

From the six communities where caldo de piedra is consumed that overlap with the CONABIO species distribution model (Ochoa-Ochoa and Flores-Villela 2016), only in one, has the species presence been confirmed. It is necessary to verify that the species occurs in the remaining five communities, and if so, whether or not it is used in tadpole soup. The new record from Santa Cruz Tepetotutla confirms that the species occurs in a locality not included in any distribution model, and it represents the only instance where *D. ignicolor* tadpoles are consumed in caldo de piedra.

The information gathered can give a better perspective of the pressure factors to which the species is exposed. The conservation status of *D. ignicolor* has been recently changed from Endangered (EN) to Near Threatened (NT) as it occurs in an Indigenous and Community Conserved Area (ICCA's) (IUCN 2020). Even when some populations distribute within protected land, pressure factors occurring in the area like chytridiomycosis, land-use change, reduced availability of ideal streams and tadpole consumption, can affect this species.

Finally, we consider that the recent increase in studies on larval stages (Rivera-Correa et al. 2021) is of vital importance for the conservation of amphibians. A broader knowledge of biology, behavior, and the natural history of adult and larval stages (Malagoli et al. 2021) should allow the design of appropriate conservation measures for organisms with complex life cycles like amphibians.

Acknowledgements

We thank Pedro Osorio-Hernandez for sharing his knowledge during the field work, and the interviewees and the authorities of Santa Cruz Tepetotutla for allowing us to work in their community. María de los Ángeles Ríos, Library Coordinator for the CIESAS-Pacífico Sur, as well as those responsible for the Welte Institute and Juan de Córdova libraries allowing us to review literature in their care for this research. Allegra Noe Burger provided comments on this manuscript. Dr. Richard Wassersug and Dr. Annemarie Ohler reviewed and provided comments to improve the final manuscript. This work was financed by SEP-CONACYT Mexico Ciencia básica project # 256071. In memory of Eugui Roy.

References

Afonso LG, Eterovick PC (2007) Microhabitat choice and differential use by anurans in forest streams in southeastern Brazil. Journal of Natural History 41(13–16): 937–948. https://doi.org/10.1080/00222930701309544

Aguilar LJL, Luría MR (2016) Los anfibios en la cultura mexicana. Ciencia 67(2): 1–8.

Akinyemi AF, Ogaga ED (2015) Frog consumption pattern in Ibadan, Nigeria. Journal for Studies in Management and Planning 3(1): 522–531.

Baird SF (1854) Descriptions of new genera and species of North American frogs. Proceedings. Academy of Natural Sciences of Philadelphia 7: 59–62.

Biju SD, Bossuyt F (2003) New frog family from India reveals an ancient biogeographical link with the Seychelles. Nature 425(6959): 711–714. https://doi.org/10.1038/nature02019

Blasco R, Blain HA, Rosell J, Díez JC, Huguet R, Rodríguez J, Arsuaga JL, Bermúdez De Castro JM, Carbonell E (2011) Earliest evidence for human consumption of tortoises in the European Early Pleistocene from Sima del Elefante, Sierra de Atapuerca, Spain. Journal of Human Evolution 61(4): 503–509. https://doi.org/10.1016/j.jhevol.2011.06.002

Blaustein AR, Waldman B (1992) Kin recognition in anuran amphibians. Animal Behaviour 44: 207–221. https://doi.org/10.1016/0003-3472(92)90027-7

Blaustein AR, Walls CS (1995) Aggregation and kin recognition. In: Heatwole H, Sullivan BK (Eds.) Amphibian biology, Vol 2. Social behavior. Surrey, Beatty and Sons, Chipping, Norton, 568–602.

Borges-Júnior VNT, Rocha CFD (2013) Tropical tadpole assemblages: Which factors affect their structure and distribution? Oecologia Australis 17(2): 217–228. https://doi.org/10.4257/oeco.2013.1702.04

Bost JA (2009) Edible plants of the Chinantla, Oaxaca, Mexico with an emphasis on the participatory domestication prospects of *Persea schideana*. PhD Thesis, University of Florida, USA, 113 pp. https://ufdc.ufl.edu/UFE0024534/00001

Boulenger GA (1883) Descriptions of new species of lizards and frogs collected by Herr A. Forrer in Mexico. Annals & Magazine of Natural History 5(11): 342–344. https://doi.org/10.1080/00222938309459162

Brandon RA, Maruska EJ, Rumph WT (1981) A new species of neotenic *Ambystoma* (Amphibia, Caudata) endemic to Laguna Alchichica, Puebla, Mexico. Bulletin of the Southern California Academy of Sciences 80: 112–125.

Brulotte RL, Starkman A (2014) Caldo de Piedra and Claiming Pre-Hispanic Cuisine as Cultural Heritage. In: Brulotte RL, Di Giovine M (Eds) Edible Identities: Food as Cultural Heritage. Ashgate Publishing, Farnham, UK, 109–123. https://doi.org/10.4324/9781315578781-8

Caldwell JP (1974) Tropical treefrog communities: patterns of reproduction, size, and utilization of structural habitat. Ph.D. dissertation. University of Kansas, Lawrence.

Campbell JA, Duellman WE (2000) New species of stream-breeding hylid frogs from the northern versant of the highlands of Oaxaca, Mexico. Scientific Papers. Natural History Museum, University of Kansas 16: 1–28. https://doi.org/10.5962/bhl.title.16165

Casas-Andreu G, Méndez de la Cruz FR, Aguilar-Miguel X (2004) Anfibios y Reptiles. In: García-Mendoza AJ, Ordoñez J, Briones-Salas M (Eds) Biodiversidad de Oaxaca. Instituto de Biología, Universidad Nacional Autónoma de México. Fondo Oaxaqueño para la Conservación de la Naturaleza. World Wildlife Fund, México, 375–390.

Chaves WA, Monroe MC, Sieving KE (2019) Wild Meat Trade and Consumption in the Central Amazon, Brazil. Human Ecology 47: 733–746. https://doi.org/10.1007/s10745-019-00107-6

Cooke GR (1989) Anurans as human food in tropical America: Ethnographic, ethnohistoric and archaeologic evidence. Archaeozoologia 3(1): 123–142.

Cope ED (1863) On *Trachycephalus*, *Scaphiopus* and other Batrachia. Proceedings. Academy of Natural Sciences of Philadelphia 15: 43–54.

Cope ED (1864) Contributions to the herpetology of tropical America. Proceedings. Academy of Natural Sciences of Philadelphia 16: 166–181.

Departamento de Zoología, Instituto de Biología (IBUNAM) (2009) *Duellmanohyla ignicolor* (Duellman, 1961), ejemplar de: Colección Nacional de Anfibios y Reptiles (CNAR). Portal de Datos Abiertos UNAM México, Universidad Nacional Autónoma de México. http://datosabiertos.unam.mx/IBUNAM:CNAR:24801

de Teresa AP (1999) Población y recursos en la región chinanteca de Oaxaca. Desacatos 1: 1–24.

Dobson ADM, Milner-Gulland EJ, Ingram DJ, Keane A (2019) A Framework for Assessing Impacts of Wild Meat Hunting Practices in the Tropics. Human Ecology 47(3): 449–464. https://doi.org/10.1007/s10745-019-0075-6

Duellman WE (1961) Descriptions of two new species of frogs, genus *Ptychohyla*. Studies of American hylid frogs, V. University of Kansas Publications. Museum of Natural History 13: 349–357. https://doi.org/10.2307/3626762

Duellman WE (2001) Hylid frogs of Middle America. Second Edition. Society for the Study of Amphibians and Reptiles. Contributions to Herpetology. Ithaca, 1250 pp.

Dugès AAD (1870) Una nueva especie de ajolote de la Laguna de Patzcuaro. La Naturaleza 1: 241–244.

Dugès AAD (1888) Herpetología del Valle de México. La Naturaleza Serie II 1: 97–146.

Dugès AAD (1895) Description d'un Axolotl des Montagnes de las Cruces (*Amblystoma Altamirani*, *A. Dugès*). Institut Médico-Nacional, Imprimèrie du Ministère de Fomento, México, 64 pp.

Duméril AMC, Bibron G (1841) Erpétologie Générale ou Histoire Naturelle Complète des Reptiles. Librarie Enclyclopedique de Roret, Paris, 112 pp.

Eterovick PC, Lazarotti I, Franco BP, Dias CJ (2010) Seasonal variation of tadpole spatial niches in permanent streams: The roles of predation risk and microhabitat availability. Austral Ecology 35(8): 879–887. https://doi.org/10.1111/j.1442-9993.2009.02094.x

Fernández EA, Romero CR, Zavala HJ, Trejo VI, Conde AC (2012) Superficies Climáticas de Temperatura Media: Atlas Climático y de Cambio Climático del Estado de Oaxaca, México. 1a edición, Centro de Ciencias de la Atmósfera. Universidad Nacional Autónoma de México. http://atlasclimatico.unam.mx/oaxaca

GBIF.org (2021) GBIF Occurrence Download.

González-Hernández AJ (2019) Estudio etnozoológico de anfibios en el Estado de México. Tesis de maestría, Universidad Autónoma del Estado de México, 105 pp. http://ri.uaemex.mx/handle/20.500.11799/105051

Grano M (2020) The Asian market of frogs as food for humans during COVID-19. Risk and consequences for public health. Medicine Papers 6(4): 77–87.

Gratwicke B, Evans MJ, Jenkins PT, Kusrini MD, Moore RD, Sevin J, Wildt DE (2010) Is the international frog legs trade a potential vector for deadly amphibian pathogens? Frontiers in Ecology and the Environment 8(8): 438–442. https://doi.org/10.1890/090111

Gravenhorst JLC (1829) Deliciae Musei Zoologici Vratislaviensis. Fasciculus primus. Chelonios et Batrachia. Leopold Voss, Leipzig, 106 pp.

Günther ACLG (1901) Reptilia and Batrachia. In: Salvin O, Godman FD (Eds) Biologia Centrali Americana, Volume 7, Part 166. R.H. Porter and Dulau and Company, London, 326 pp.

Hase K, Kutsukake N (2019) Developmental effects on social preferences in frog tadpoles, *Rana ornativentris*. Animal Behaviour 154: 7–16. https://doi.org/10.1016/j.anbehav.2019.06.001

Hillis DM, Frost JS (1985) Three new species of leopard frogs (*Rana pipiens* complex) from the Mexican Plateau. Occasional Papers of the Museum of Natural History, University of Kansas 117: 1–14.

Hoffmann M, Hilton-Taylor C, Angulo A, Böhm M, Brooks TM, Butchart SHM, Cox NA, Carpenter KE, Chanson J, Collen B, Darwall WRT, Dulvy NK, Harrison LR, Katariya V, Pollock CM, Quader S, Richman NI, Rodrigues ASL, Tognelli MF, Vié JC, Aguiar JM, Allen DJ (2010) The impact of conservation on the status of the world's vertebrates. Science 330(6010): 1503–1509. https://doi.org/10.1126/science.1194442

Huacuz D (2002) Programa de conservación y manejo de *Ambystoma dumerilii* el achoque del lago de Pátzcuaro. Universidad Michoacana de San Nicolás de Hidalgo, Fondo Mexicano para la Conservación de la Naturaleza, A.C. Secretaría de Ambiente y Recursos Naturales. Morelia, Michoacán, 138 pp.

Ibarra J, del Campo C, Barreau A, Medinaceli A, Camacho CI, Puri R, Martin GJ (2011) Etnoecología Chinanteca: Conocimiento, Práctica y Creencias Sobre Fauna y Cacería en un Área de Conservación Comunitaria de La Chinantla, Oaxaca, México. Etnobiología 9(1): 36–58.

INEGI (2010) Clasificación de lenguas indígenas Instituto Nacional de Estadística y Geografía. INEGI, c2014, México, VII, 14 pp.

INEGI (2014) Conjunto de datos vectoriales de información topográfica E14D18 (San Felipe Usila) escala 1:50 000 serie III. https://datos.gob.mx/busca/dataset/mapas-topograficos-escala-1-50-000-serie-iii-oaxaca/resource/b6c05400-36b9-40c4-bfa5-547ff3036072

INPI-INALI (2020) Atlas de los pueblos indígenas de México. Instituto Nacional de los Pueblos Indígenas. http://atlas.inpi.gob.mx/chinantecos-etnografia/

IUCN (2021a) The IUCN Red List of Threatened Species. Version 2021–1. https://www.iucnredlist.org

IUCN SSC Red List Technical Working Group (2021b) Mapping Standards and Data Quality for the IUCN Red Spatial Data. V1.19 (May 2021). https://www.iucnredlist.org/resources/mappingstandards

IUCN SSC Amphibian Specialist Group (2020) *Duellmanohyla ignicolor*. The IUCN Red List of Threatened Species 2020: e.T55308A53951963.

Kats BL, Ferrer PR (2003) Alien predators and amphibian declines: Review of two decades of science and the transition to conservation. Diversity & Distributions 9(2): 99–110. https://doi.org/10.1046/j.1472-4642.2003.00013.x

Kusrini MD, Alford RA (2006) Indonesia's Exports of Frogs' Legs. Traffic Bulletin 21(1): 13–24.

Kyselý R (2008) Frogs as a part of the Eneolithic diet. Archaeozoological records from the Czech Republic (Kutná Hora-Denemark site, Řivnáč Culture). Journal of Archaeological Science 35(1): 143–157. https://doi.org/10.1016/j.jas.2007.02.016

Linnaeus CF (1753) Species Plantarum. Holmia, 626 pp.

Malagoli LR, Pezzuti TL, Bang DL, Faivovich J, Lyra ML, Giovanelli JGR, de Anchietta Garcia PC, Sawaya RJ, Haddad CFB (2021) A new reproductive mode in anurans: natural history of *Bokermannohyla astartea* (Anura: Hylidae) with the description of its tadpole and vocal repertoire. PLoS ONE 16(2): 1–30. https://doi.org/10.1371/journal.pone.0246401

Mata-Silva V, García-Padilla E, Rocha A, DeSantis D, Johnson J, Ramírez-Bautista A, Wilson L (2021) A reexamination of the herpetofauna of Oaxaca, Mexico: composition update, physiographic distribution, and conservation commentary. Zootaxa 4996(2): 201–252. https://doi.org/10.11646/zootaxa.4996.2.1

McDiarmid RW, Altig R (1999) Tadpoles: the biology of anuran larvae. University of Chicago Press, Chicago, 458 pp.

Mejía MC, González SF (2019) La Chinantla: Crónicas gastronómicas. Universidad del Papaloapan, Secretaría de las Culturas y Artes de Oaxaca, 127 pp.

Mey E, ex Schult (1822) In: Mant. 1: 8.

Museo de Zoología de la Facultad de Ciencias, UNAM (2018) Colección de Herpetología, MZFC-UNAM.

Nahmad S (2003) Fronteras étnicas análisis y diagnóstico de dos sistemas de desarrollo: proyecto nacional vs. proyecto étnico. El caso de los "ayuuk" (mixes) de Oaxaca. México, Ciesas, 673 pp.

Ochoa-Ochoa LM, Flores-Villela OA (2016) *Duellmanohyla ignicolor* (rana arroyera de Sierra de Juárez). Distribución potencial actual, escala: 1:1000000. edición: 2. Facultad de Ciencias, Universidad Nacional Autónoma de México. Proyecto: JM022, Anfibiofauna endémica frente al cambio climático: análisis de sensibilidad e incertidumbre. CONABIO. Ciudad de México, México.

Ohler A, Nicolas V (2017) Which frog's legs do froggies eat? The use of DNA barcoding for identification of deep frozen frog legs (Dicroglossidae, Amphibia) commercialized in France. European Journal of Taxonomy 271(271): 1–11. https://doi.org/10.5852/ejt.2017.271

Onadeko AB, Egonmwan RI, Saliu JK (2011) Edible amphibian species: Local knowledge of their consumption in Southwest Nigeria and their nutritional value. West African Journal of Applied Ecology 19(1): 67–76.

Ortiz-Pérez MA, Hernández-Santana JR, Figueroa-Mah-Eng JM (2004) Reconocimiento fisiográfico y geomorfológico. In: García-Mendoza AJ, Ordoñez MJ, Briones-Salas MJ, Biodiversidad de Oaxaca (Eds) Universidad Autónoma de México, Fondo oaxaqueño para la Conservación de la Naturaleza y WWF, México, 43–544.

Parra-Olea G, García-Castillo MG, Rovito SM, Maisano JA, Hanken J, Wake DB (2020) Descriptions of five new species of the salamander genus *Chiropterotriton* (Caudata: Plethodontidae) from eastern Mexico and the status of three currently recognized taxa. PeerJ, 2020(5): 1–71. https://doi.org/10.7717/peerj.8800

Quantum GIS Development Team (2021) Quantum GIS Geographic Information System. Open-Source Geospatial Foundation Project. www.qgis.com

Ripple WJ, Wolf C, Newsome TM, Betts MG, Ceballos G, Courchamp F, Hayward MW, Valkenburgh BW, Wallach AD, Worm B (2019) Are we eating the world's megafauna to extinction? Conservation Letters 12(3): 1–10. https://doi.org/10.1111/conl.12627

Rivera-Correa M, Baldo D, Candioti FV, Goyannes V, Gambale P, Gower DJ, Quah ESH, Rowley JJL, Twomey E (2021) Amphibians in Zootaxa: 20 years documenting the global diversity of frogs, salamanders, and caecilians. Zootaxa 4979(1): 57–69. https://doi.org/10.11646/zootaxa.4979.1.9

Sánz JP (2015) Cómo se calentaba el caldo prehistórico. Boletín de Arqueología Experimental 10: 174–182.

Shaw G (1802) General Zoology or Systematic Natural History. Volume III, Part 1. Amphibia. London: Thomas Davison. https://doi.org/10.5962/bhl.title.1593

Shaw G, Nodder FP (1798) The Naturalist's Miscellany; or Coloured Figures of Natural Objects Drawn and Described Immediately from Nature. Volume 9. Nodder and Company, London, 287 pp.

Simón-Salvador PR, Arreortúa M, Flores CA, Santiago-Dionicio H, González-Bernal E (2021) The role of Indigenous and Community Conservation Areas in herpetofauna conservation: A preliminary list for Santa Cruz Tepetotutla, Oaxaca Mexico. ZooKeys 1029: 185–208. https://doi.org/10.3897/zookeys.1029.62205

Spieler M (2003) Risk of predation affects aggregation size: a study with tadpoles of *Phrynomantis microps* (Anura: Microhylidae). Animal Behaviour 65(1): 179–184. https://doi.org/10.1006/anbe.2002.2030

Stuart SN, Chanson JS, Cox NA, Young BE, Rodrigues ASL, Fischman DL, Waller RW [Eds] (2004) Status and trends of amphibian declines and extinctions worldwide. Science 306(5702): 1783–1786. https://doi.org/10.1126/science.1103538

Stuart SN, Chanson JS, Cox NA, Young BE (2010) The global decline of amphibians: Current trends and future prospects. In: Wilson LD, Townsend JH, Johnson JD (Eds)

Conservation of Mesoamerican Amphibians and Reptiles. Eagle Mountain Publishing, LC, Eagle Mountain, Utah, USA, 2–15.

Talukdar S, Sengupta S (2020) Edible frog species of Nagaland. Journal of Environmental Biology 41(4(SI)): 927–930. https://doi.org/10.22438/jeb/4(SI)/MS_1918

Taylor EH (1939) New salamanders from Mexico, with a discussion of certain known forms. The University of Kansas Science Bulletin 26: 407–430.

Taylor EH (1944) A new ambystomid salamander from the Plateau Region of Mexico. The University of Kansas Science Bulletin 30: 57–61. https://doi.org/10.5962/bhl.part.6502

Thomas A, Biju SD (2015) Tadpole consumption is a direct threat to the endangered purple frog, *Nasikabatrachus sahyadrensis*. Salamandra (Frankfurt) 51(3): 252–258.

Thoms AV (2008) The fire stones carry: Ethnographic records and archaeological expectations for hot-rock cookery in western North America. Journal of Anthropological Archaeology 27(4): 443–460. https://doi.org/10.1016/j.jaa.2008.07.002

Thoms AV (2009) Rocks of ages: Propagation of hot-rock cookery in western North America. Journal of Archaeological Science 36(3): 573–591. https://doi.org/10.1016/j.jas.2008.11.016

Tyler MJ, Wassersug R, Smith B (2007) How frogs and humans interact: Influences beyond habitat destruction, epidemics and global warming. Applied Herpetology 4(1): 1–18. https://doi.org/10.1163/157075407779766741

Velarde MT (2012) Importancia ecológica y cultural de una especie endémica de ajolote (*Ambystoma dumerilii*) del Lago de Pátzcuaro, Michoacán. Etnobiología 10: 40–49.

Weitlaner R (1951) Sobre la alimentación chinanteca. Anales del Instituto Nacional de Antropologia e Historia 33(5): 177–195.

Whittaker K, Koo MS, Wake DB, Vredenburg VT (2013) Global Declines of Amphibians. In: Levin SA (Ed.) Encyclopedia of Biodiversity. USA Academic Press, 691–699. https://doi.org/10.1016/B978-0-12-384719-5.00266-5

Wiegmann AFA (1833) Herpetologische Beyträge. I. Ueber die mexicanischen Kröten nebst Bemerkungen über ihnen verwandte Arten anderer Weltgegenden. Isis von Oken 26: 651–662.